

1 WHAT IS CLAIMED IS:

1. A method for obtaining a numerical value from a fingerprint comprising the steps of:

enhancing a scanned image of the fingerprint;
5 restoring the enhanced image;
binarizing the restored image;
thinning the binarized image;
detecting a core point in the thinned image;
detecting minutiae within a predetermined radius from the
10 core point; and
extracting the numerical value by computing relations of the minutiae to the core point.

2. The method of claim 1, wherein the step of enhancing
15 comprises the steps of:

enhancing the contrast of each ridge in the image;
filtering noise;
partition a ridge area from a blank area by sharpening edges
of each ridge; and
20 smoothening rough edges of each ridge.

3. The method of claim 1, wherein the step of restoring
comprises the steps of:

correcting geometric distortion of the image; and
25 applying inverse filtering to the image.

4. The method of claim 1, wherein the step of restoring
comprises the steps of:

correcting geometric distortion of the image; and
30 applying least square filtering to the image.

5. The method of claim 1, wherein the step of binarizing
comprises the step of converting the image to a black and white
image.

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- 1 6. The method of claim 1, wherein the step of binarizing
comprises the steps of:
 setting a predetermined threshold level;
 changing a point in a line to a black color if the point
5 intensity is lower than the threshold value.
7. The method of claim 1, wherein the step of binarizing
comprises the steps of:
 partitioning the image into a plurality of smaller areas;
10 computing average intensity level of line within each
smaller area;
 setting the intensity level of each smaller area as a
threshold level for the respective area; and
 transforming gray-scale image of each smaller area to a
15 binary image.
8. The method of claim 1, wherein the step of thinning
comprises the step of reducing the width of each black line in
the image to one pixel.
- 20 9. The method of claim 1, wherein the step of detecting
a core point comprises the steps of:
 determining a core area; and
 detecting a core point in the determined core area.
- 25 10. The method of claim 9, wherein the step of determining
a core area comprises the steps of:
 segmenting the image into smaller areas;
 applying a FFT process to each segmented smaller area;
30 extracting a direction line for each line in the each
smaller area to obtain an image of a respective directional
straight line for each smaller area;
 classifying each directional line to a vertical, a
horizontal, a left slope, and a right slope type;
35 assigning a respective flag to each of the classified

1 directional lines to obtain a matrix with columns and rows,
wherein each column of the matrix includes a plurality of smaller
areas;

5 determining a core area in a column with most number of
vertical directional lines; and

determining a core area in a segmented smaller area whose
each of its upper smaller areas in the respective column include
a vertical directional lines.

10 11. The method of claim 10, wherein the step of determining
a core point in the determined core area comprises the steps of:

segmenting the determined core area into smaller squares;

applying a FFT process to each segmented smaller square;

15 extracting a direction line for each line in the each
smaller square to obtain an image of a directional straight line
for each smaller square;

classifying each directional line to a vertical, a
horizontal, a left slope, and a right slope type;

20 assigning a respective flag to each of the classified
directional lines to obtain a matrix with columns and rows,
wherein each column of the matrix includes a plurality of
squares;

determining a core square in a column with most number of
vertical directional lines;

25 determining a core square in a segmented smaller square
whose each of its upper smaller squares in the respective column
include a vertical directional lines; and

determining a highest pixel on a ridge line in the core
square.

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12. The method of claim 1, wherein the step of detecting
minutiae comprises the step of detecting bifurcation minutiae.

35 13. The method of claim 12, wherein the step of detecting
minutiae comprises the steps of:

- 1 dividing the image to a plurality of 3 X 3 pixel squares;
for each of the plurality of squares:
counting the number of color changes from black to
white, starting at the center pixel;
- 5 assigning the number to the central pixel; and
determining pixels with an assigned number of 3 as
bifurcation minutiae.

14. The method of claim 1, wherein the step of extracting
10 the numerical value comprises the steps of:
ordering the detected minutiae by their respective distance
from the detected core point as $b_1, b_2, b_3, \dots b_n$, wherein b is a
detected minutia and n is the total number of detected minutiae;
computing a distance between the core point and b_1 as d_1 ;
- 15 computing a distance between b_1 and b_2 as d_2 ;
computing a radius r_1 of a circle including the core point,
 b_1 , and b_2 on its circumference;
- for each of the remaining minutiae b_i , from b_3 to b_n :
computing a distance between b_{i-1} and b_i as d_i ;
- 20 computing a radius r_{i-1} of a circle including b_{i-2}, b_{i-1} ,
and b_i on its circumference; and
assembling the numerical value by combining $d_1 d_2 r_1 d_3 r_2 d_4 r_3$
..... $d_n r_{n-1}$.

- 25 15. The method of claim 1, further comprising the step of
utilizing the extracted numerical value as a key for data
encryption.

- 30 16. The method of claim 1, further comprising the step of
utilizing the extracted numerical value for data authentication
for online shopping.

- 35 17. The method of claim 1, further comprising the step of
utilizing the extracted numerical value for a cardless secure
transaction.

1 18. The method of claim 1, wherein the transaction is performed over the Internet.

5 19. A fingerprint scanning device comprising:
means for scanning a fingerprint for obtaining a fingerprint image;
means for enhancing the fingerprint image;
means for restoring the fingerprint image;
means for binarizing the fingerprint image;
10 means for thinning the fingerprint image;
means for detecting a core point in the fingerprint image;
means for detecting minutiae within a predetermined radius from the core point; and
means for extracting the numerical value by computing
15 relations of the minutiae to the core point.

20 20. The device of claim 19, wherein the means for enhancing comprises:
means for enhancing the contrast of each ridge in the image;
20 means for filtering noise;
means for partition a ridge area from a blank area by sharpening edges of each ridge; and
means for smoothening rough edges of each ridge.

25 21. The device of claim 19, wherein the means for restoring comprises:
means for correcting geometric distortion of the image; and
means for applying inverse filtering to the image.

30 22. The device of claim 19, wherein the means for restoring comprises:
means for correcting geometric distortion of the image; and
means for applying least square filtering to the image.

35 23. The device of claim 19, wherein the means for

1 binarizing comprises means for converting the image to a black
and white image.

24. The device of claim 19, wherein the means for
5 binarizing comprises:

means for setting a predetermined threshold level;

means for changing a point in a line to a black color if the
point intensity is lower than the threshold value.

10 25. The device of claim 19, wherein the means for
binarizing comprises:

means for partitioning the image into a plurality of smaller
areas;

15 means for computing average intensity level of line within
each smaller area;

means for setting the intensity level of each smaller area
as a threshold level for the respective area; and

means for transforming gray-scale image of each smaller area
to a binary image.

20 26. The device of claim 19, wherein the means for thinning
comprises means for reducing the width of each black line in the
image to one pixel.

25 27. The device of claim 19, wherein the means for detecting
a core point comprises:

means for determining a core area; and

means for detecting a core point in the determined core
area.

30 28. The device of claim 27, wherein the means for
determining a core area comprises:

means for segmenting the image into smaller areas;

35 means for applying a FFT process to each segmented smaller
area;

1 means for extracting a direction line for each line in the
each smaller area to obtain an image of a respective directional
straight line for each smaller area;

means for classifying each directional line to a vertical,
5 a horizontal, a left slope, and a right slope type;

means for assigning a respective flag to each of the
classified directional lines to obtain a matrix with columns and
rows, wherein each column of the matrix includes a plurality of
smaller areas;

10 means for determining a core area in a column with most
number of vertical directional lines; and

means for determining a core area in a segmented smaller
area whose each of its upper smaller areas in the respective
column include a vertical directional lines.

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29. The device of claim 28, wherein the means for
determining a core point in the determined core area comprises:

means for segmenting the determined core area into smaller
squares;

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means for applying a FFT process to each segmented smaller
square;

means for extracting a direction line for each line in the
each smaller square to obtain an image of a directional straight
line for each smaller square;

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means for classifying each directional line to a vertical,
a horizontal, a left slope, and a right slope type;

means for assigning a respective flag to each of the
classified directional lines to obtain a matrix with columns and
rows, wherein each column of the matrix includes a plurality of
30 smaller squares;

means for determining a core square in a column with most
number of vertical directional lines;

means for determining a core square in a segmented smaller
area whose each of its upper smaller areas in the respective
35 column include a vertical directional lines; and

1 means for determining a highest pixel on a ridge line in the
core square.

30. The device of claim 19, wherein the means for detecting
5 minutiae comprises means for detecting bifurcation minutiae.

31. The device of claim 30, wherein the means for detecting
minutiae comprises:

means for dividing the image to a plurality of 3 X 3 pixel
10 squares;

for each of the plurality of squares:

means for counting the number of color changes from
black to white, starting at the center pixel;

means for assigning the number to the central pixel;

15 and

means for determining pixels with an assigned number
of 3 as bifurcation minutiae.

32. The device of claim 19, wherein the means for
20 extracting the numerical value comprises:

means for ordering the detected minutiae by their respective
distance from the detected core point as $b_1, b_2, b_3, \dots b_n$,
wherein b is a detected minutia and n is the total number of
detected minutiae;

25 means for computing a distance between the core point and
 b_1 as d_1 ;

means for computing a distance between b_1 and b_2 as d_2 ;

means for computing a radius r_1 of a circle including the
core point, b_1 , and b_2 on its circumference;

30 for each of the remaining minutiae b_i , from b_3 to b_n :

means for computing a distance between b_{i-1} and b_i as d_i ;

means for computing a radius r_{i-1} of a circle including
 b_{i-2}, b_{i-1} , and b_i on its circumference; and

means for assembling the numerical value by combining
35 $d_1 d_2 r_1 d_3 r_2 d_4 r_3 \dots d_n r_{n-1}$.

1 33. The device of claim 19, further comprising means for
utilizing the extracted numerical value as a key for data
encryption.

5 34. The device of claim 19, further comprising means for
utilizing the extracted numerical value for data authentication
for online shopping.

10 35. The device of claim 19, further comprising means for
utilizing the extracted numerical value for a cardless secure
transaction.

15 36. The device of claim 19, wherein the transaction is
performed over the Internet.

20 37. A computer readable medium having stored thereon a set
of instructions including instruction for obtaining a numerical
value from a fingerprint, the instructions, when executed by a
computer cause the computer to perform the steps of:

25 enhancing a scanned image of the fingerprint;
restoring the fingerprint image;
binarizing the fingerprint image;
thinning the fingerprint image;
detecting a core point in the fingerprint image;
30 detecting minutiae within a predetermined radius from the
core point; and

35 extracting the numerical value by computing relations of the
minutiae to the core point.